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APPLICATIONS OF ERTS-I DATA TO LANDSCAPE CHANGE IN EASTERN TENNESSEE

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BIOGRAPHICAL SKETCH

Dr. John B. Rehder received his B.A. from East Carolina University in 1963, and his Ph.D. from Louisiana State in 1971. Research and travel with scholarly intent has carried him throughout the Southeastern United States, the West Indies, Alpine France, and Panama. His teaching and research specialties include cultural geography, rural settlement geography, and remote sensing. Presently, his publications total 16. His current research activity is concentrated in remote sensing in which he is director and principal investigator for the NASA-ERTS Geography Remote Sensing Project: "Geographic Applications of ERTS-A Imagery to Rural Landscape Change." Dr. Rehder is assistant professor of Geography at the University of Tennessee, a position which he has held since 1967.

ABSTRACT

The analysis of landscape change in eastern Tennessee from ERTS-I data is being derived from three avenues of experimentation and analysis: (1) a multi-stage sampling procedure utilizing ground and aircraft imagery for ground truth and control, (2) a densitometric and computer analytical experiment for the analysis of gray tone signatures and comparisons for landscape change detection and monitoring, and (3) an ERTS image enhancement procedure for the detection and analysis of photomorphic regions. Significant results include: maps of strip mining changes and forest inventory, watershed identification and delimitation, and agricultural regions derived from spring plowing patterns appearing on the ERTS-I imagery.

INTRODUCTION

The capabilities of ERTS-I in sensing the same geographic point every 18 days and providing a 13,225 square mile view from each image enable us to analyze landscape change from a geographic perspective. The investigation focuses on the East Tennessee Test Site, a 20,000 square mile region in which landscape change elements such as forest alterations, strip mines, highway construction, urban-suburban growth, and cyclic seasonal changes in agriculture are being analyzed (Figure 1). Two smaller test sites are being studied within the larger test region. The Knoxville Test Site, an 11 x 21 mile area which encompasses the city of Knoxville and the western portion of Knox County, is being investigated for landscape change associated with urban growth. A second smaller test site on the Cumberland Plateau is being monitored for forest alterations and landform disturbances associated with the surface strip mining of coal.[1]

Three avenues of experimentation and analysis are being used in the investigation: (1) a multi-stage, multi-scale sampling procedure, (2) a densitometric and computer analytical experiment, and (3) an image enhancement procedure.

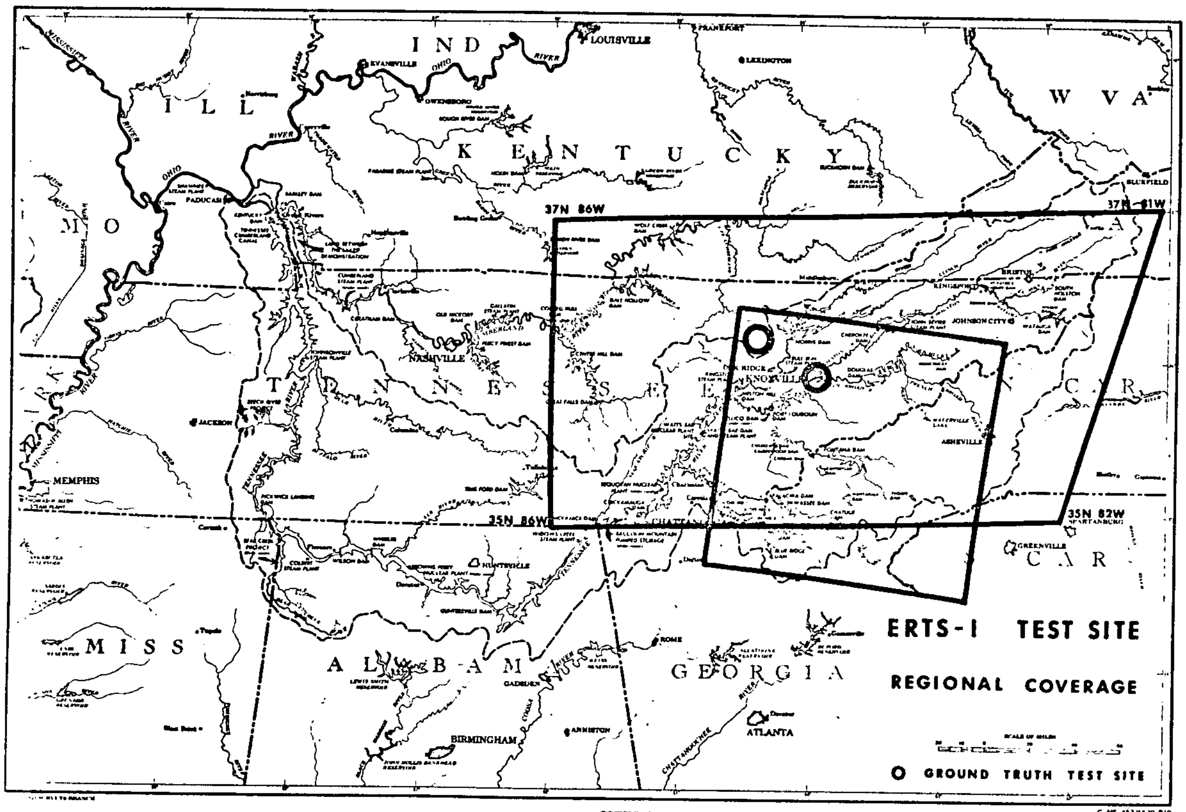

FIGURE 1

Figure 1 - The East Tennessee Test Site with a representative ERTS frame for scale.

The multi-stage sampling experiment has involved the generation and analysis of surface ground truth imagery, low altitude imagery flown from 7,000' in April, 1973, high altitude aircraft imagery from a NASA RB-57 overflight at 60,000' in April, 1972, and the ERTS-I imagery since August, 1972.

Surface ground truth investigations of strip mining activities were conducted on the Cumberland Plateau with particular emphasis given to one of the more active mines in the area as located by the arrow on figure 5. Ground observations were made and photographed to illustrate the internal characteristics of the surface mines. Figure 2 illustrates the nature of cuts, road beds, and fill materials. Revegetation and reclamation work in the form of reseeded spoil banks was verified for the area. In contrast to data that had been derived from the ERTS and aircraft imagery, the surface ground truth investigation provided positive evidence of details within the surface mines as well as detailed information about the reclamation of abandoned mines.

At a second stage of the multi-scale procedure, a low altitude aircraft mission was flown on April 13, 1973, over the Cumberland Plateau Test Site at 7,000' to obtain aircraft imagery of the strip mines (Figure 3).

The four images in Figure 3 are 70 mm contact negative prints of selected strip mine operations. Image 1 illustrates the nature of a newly cleared (deforested) swath of ground which has been prepared in anticipation of continued strip mining of coal. This clearing represents the initial landscape change activity in strip mining. Because of the high reflectance of the sandstone surface, the cleared area appears "brighter" than the surrounding forested background. (Note all illustrations shown here are negative prints, thus dark

Figure 2. Ground truth photograph of a strip mine. Cumberland Plateau, Tennessee.

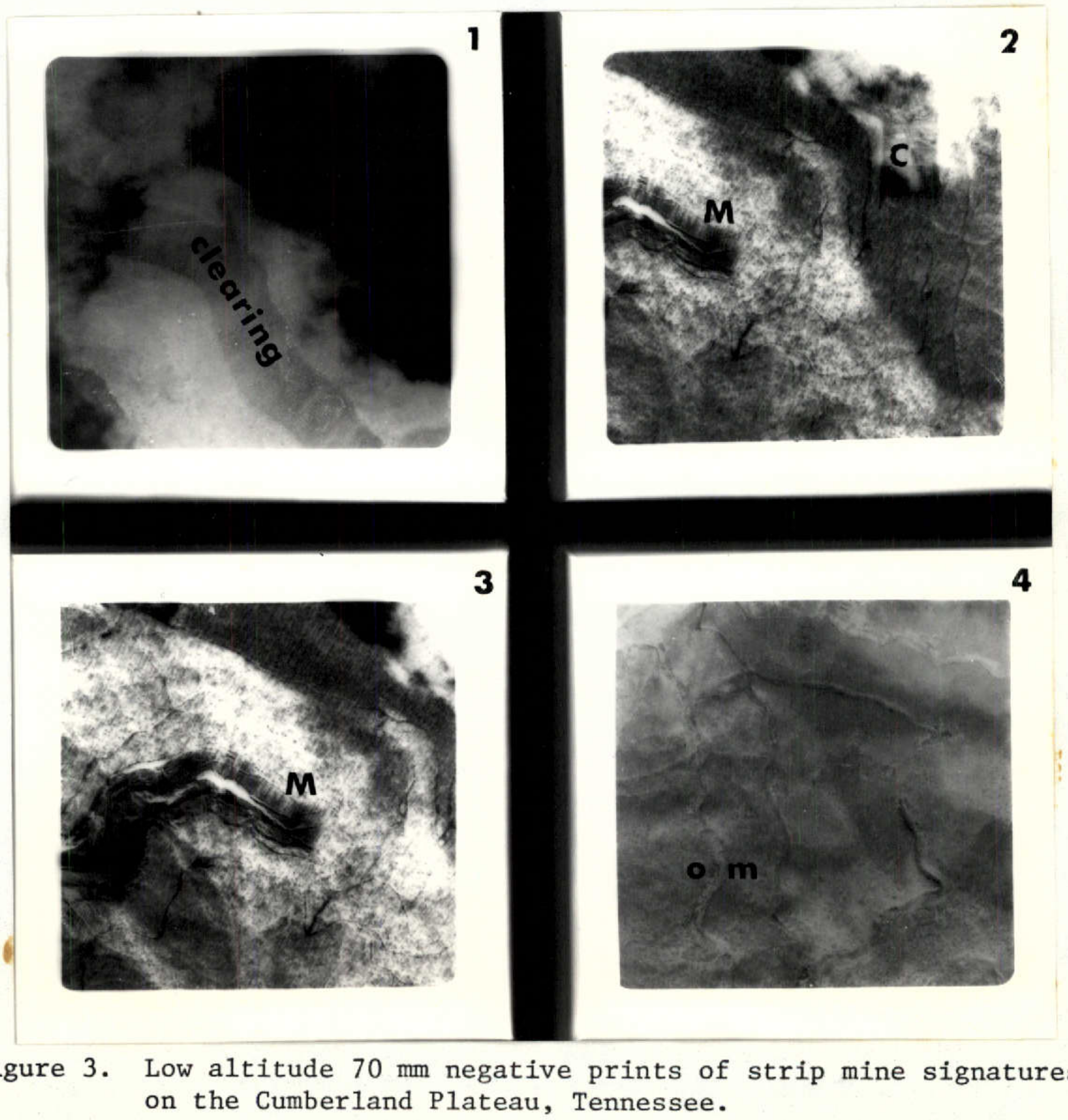

Figure 3. Low altitude 70 mm negative prints of strip mine signatures on the Cumberland Plateau, Tennessee.

tones are in reality light, bright tones on the original color infrared and ektachrome imagery).[2] Additionally, the swath in image 1 also appears on the ERTS image for October 15, 1972 (see Figure 5).

Image 2 of the 70 mm negative prints illustrates the surface contrasts between a swath of newly cleared land (at C) and a swath of land actually being stripped for coal at the cutting edge of the strip mine operation (M). Image 3 further illustrates the same active mine as in image 2. Here one can detect a rough gouged surface, road tracks, deep pits where an auger is being used, and in general the roughened signature of an active strip mine. Image 4 illustrates the relative healing of old strip mine scars (OM). Although they are quite visible from this altitude of 7,000', they do not clearly appear on the ERTS imagery. A characteristic signature of old strip mines, however, is their narrow width of 30' to 75' as compared with 300'-500' for the newer active mines which are wider because of more modern, wider, mining equipment. Another signature is the natural vegetation which is reclaiming the scars with pines, scrub oak, brush vegetation and around water filled depressions cat tails and other water-tolerant grasses. The smaller size of the older mines and the revegetated surfaces account for their apparent obscurity on the ERTS imagery.

The intermediate scale imagery from the April, 1972, RB-57 overflight has been most useful for control. Figure 4 of the Cumberland Plateau Test Site illustrates in a negative print the strip mine scars on the landscape for this area. At this scale one can see not only the modified land surface but also the internal characteristics of the surface mines. Note the extent of cleared, stripped land and the forested area at the bottom of the image for this observation in April. Now, in Figure 5 viewing the same area from an enhanced ERTS image for October 15, one can detect a distinct increase in dark tones indicating cleared land in the area that had been forested in April. This represents a significant landscape change.[3]

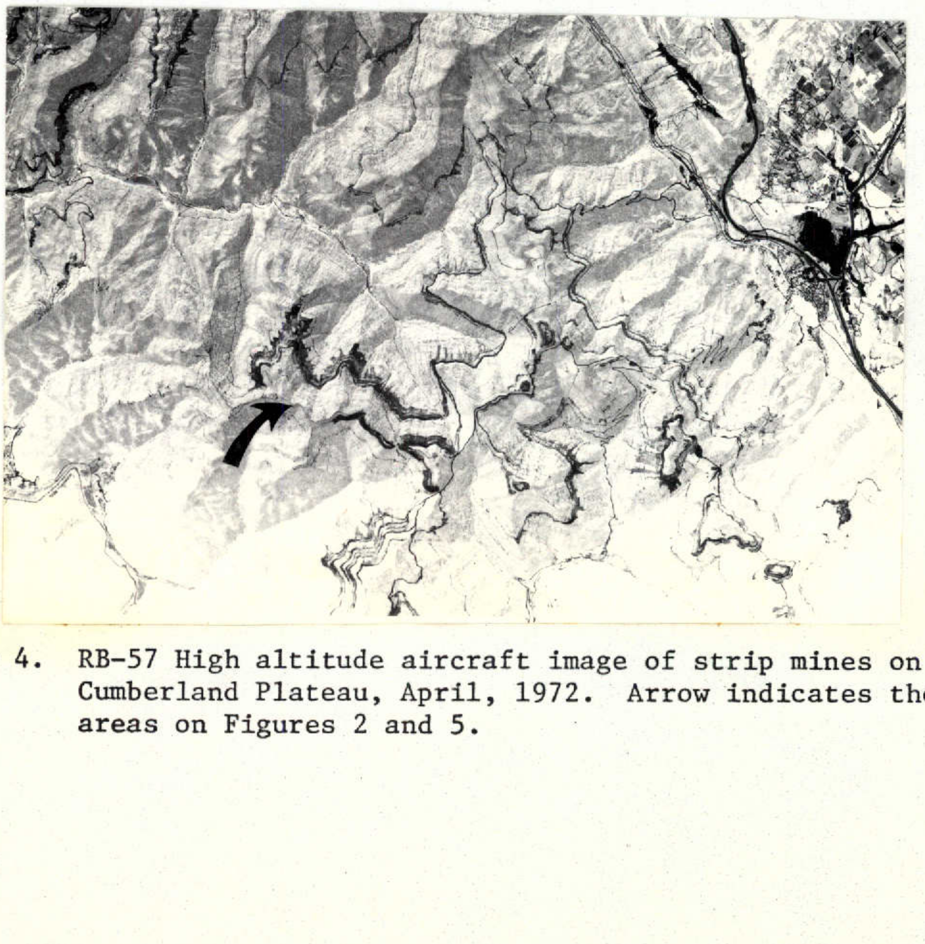

Figure 4. RB-57 High altitude aircraft image of strip mines on the Cumberland Plateau, April, 1972. Arrow indicates the mine areas on Figures 2 and 5.

Figure 5. ERTS-I Band 5 negative print of strip mines on the Cumberland Plateau, October, 1972. Arrow indicates the mine shown on Figure 2.

With regard to the mapping of landscape change parameters, we have initiated the mapping of strip mining changes on the plateau between the dates of April 18, 1972 and October 15, 1972 (Figure 6).[4]

The black shading indicates the extant surface mines as of April 1972 and the gray shading illustrates the "new" strip mines as of October 1972. Although the mapped data were derived from RB-57 aircraft and ERTS imagery and then reproduced at a scale of 1:120,000 comparable to that of the RB-57 aircraft imagery scale, the results are clear. Landscape changes are indeed rapidly taking place in a considerable area and these changes are detectable from ERTS imagery. We feel that this represents a significant result from the analysis of data from ERTS.

Microdensitometric and computer techniques are being used to analyze the ERTS imagery for gray tone signatures, comparisons, and ultimately for landscape change detection and monitoring. Using the same strip mine example from Figure 5, let's observe the same patterns of surface configuration on the computerized map (Figure 7). The experiment involves the microdensity scanning of a positive band 5 image in which strip mines appear as light tones against a dark forested background. Gray tone densities are then digitized and computer processed into a computer map and histogram (frequency distribution). By comparing such machine analyzed data from different dates of satellite observations, we can determine if the number of light tones indicating strip mined areas have increased at the expense of dark tones for the same area.

Barring extraneous signals from cloud cover, one then should be able to conclude that forest cover has been altered and strip mines have been increasing because of the increased frequency of light toned signatures.

Figure 6. Landscape change created by strip mining on the Cumberland Plateau Test Site. April - October, 1972.

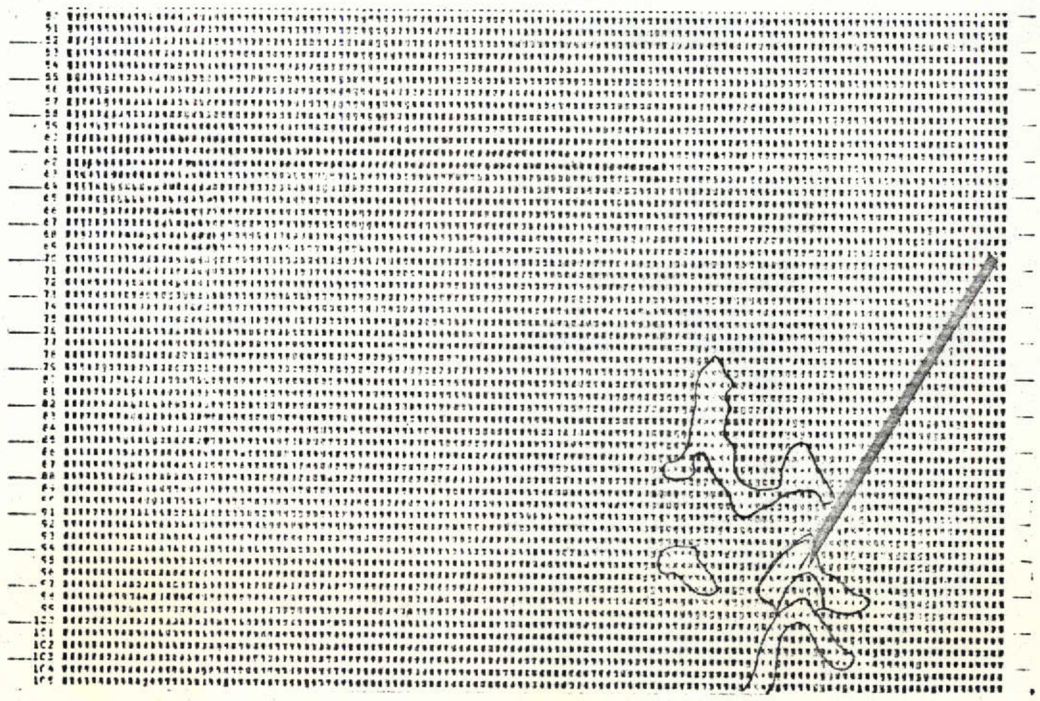

Figure 7. Microdensity scan displayed in a computer map printout illustrating the same surface mine signatures from an ERTS band 5 image. See figure 5.

Initial comparisons between two computer generated histograms representing August 22 and October 15, unfortunately resulted in the inverse from the expected. This is because only two relatively clear observations for the strip mined area had been obtained and the atmospherics on August 22 created a serious cloud and haze problem. Given time and more but clearer observations, these problems can be rectified.

In addition to this experiment, applications toward earth resources management problems involve the generation of enhanced ERTS imagery for emphasizing areas of potential and current landscape dynamics. In this regard several photomorphic regions have been under observation.

The Great Smoky Mountains represent a region of cyclic, seasonal change for which natural and not man-made causes predominate. Figure 8, a negative print from the infrared band 7, illustrates a temporary landscape change phenomenon of a surficially wetted area on the western, windward slopes of the Smokies. The day preceding this ERTS observation, a frontal disturbance deposited approximately 2"-3" of rainfall on the windward slopes. By comparison, Knoxville, located downslope in the valley received 1.12" of precipitation. The wetted surface shown here in white tones was sufficiently wet to register in tones similar to the surrounding streams and T.V.A. reservoirs to the north and west. The satellite monitoring of a water-shed such as this indeed has application toward water resources, flood prediction, and a host of other water management problems.

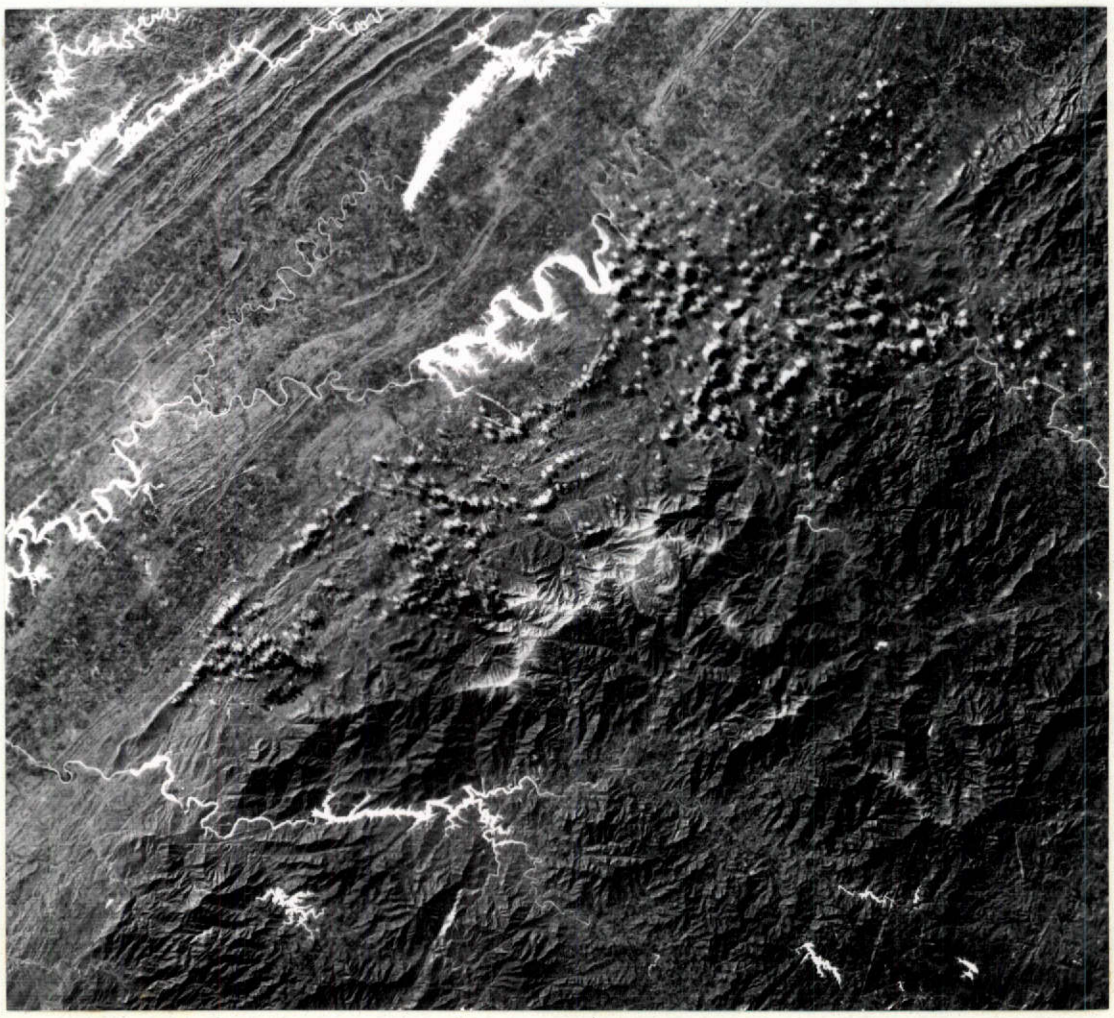

Figure 8. ERTS band 7 negative print of the East Tennessee Test Site. Note light toned wetted surface on the Great Smoky Mountains at center.

Mapping physical phenomenae from a photomorphic perspective has resulted in a generalized forest map of Tennessee (Figure 9). From 5 frames of ERTS-I imagery alone, the map of forest cover for the entire state was produced in three hours of mapping time. With ERTS, time efficiency like this indeed provides a cost benefit of many thousands of dollars and many man-days as compared with conventional methods. Had high altitude RB-57 imagery at 1:120,000 scale been the data base, the same mapping effort would have required 146 images, approximately 60 man-days, and over $150,000 worth of imagery.

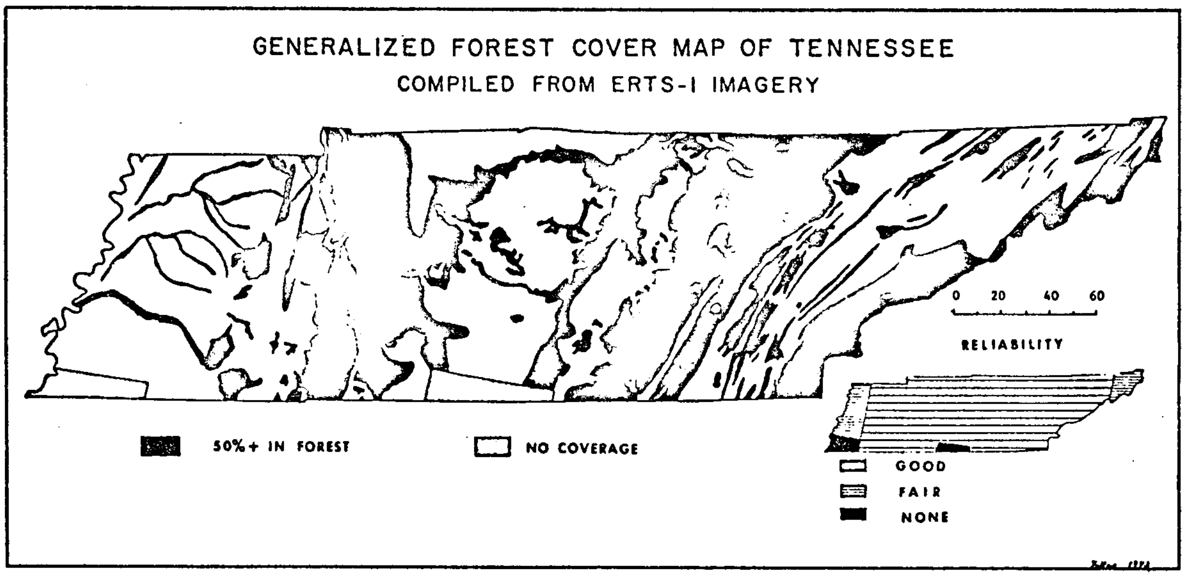

Figure 9. Forest cover in Tennessee.

One of the man-produced photomorphic regions is illustrated by the enhanced band 5 image in figure 10. Using a positive transparency as a negative we have produced a negative print on which normally light toned cultural features are enhanced as dark ones. Reading black on white, one can observe a broad agricultural area in the eastern portion of the Great Valley and the spider web effect of roads and routes leading to Knoxville. The built up area of Knoxville and suburban growth areas to its west appear much sharper on this image than on the normal black and white. The black dots and lines of deepest intensity indicate areas of highest reflectance for band 5 and generally for this area represent areas of cleared earth. Such bare soil surfaces are best illustrated by the I-81 interstate highway construction in the northeast portion of the image. Westward one can see again the strip mines enhanced as black jagged lines on the Cumberland Plateau.

One of the more significant photomorphic results concerns the detection, identification and mapping of plowed fields within the western portion of the study area. Heretofore our imagery analysis efforts have focused upon the more dynamic strip mining landscapes and the suburban growth areas west of Knoxville. The agricultural scene was initially obscure on the August imagery, almost microscopic on the October imagery, and snow covered and dormant on the January data. But for April the agricultural scene emerged as a significantly dynamic landscape surface of plowing patterns and cleared fields.

Figure 10. ERTS band 5 negative print of the East Tennessee Test Site. Note urban and agricultural areas - man-made landscapes - shown in dark tones. Disregard clouds at right.

The agricultural landscapes of East and Middle Tennessee are dominated by a chaotic pattern of tiny fields, some measuring one-third acre or less. Even the largest of fields measure no more than 50 acres. Thus we were pleasantly surprised to find that the most reflective features on the imagery were recently plowed fields which identified photomorphic agricultural regions.

Figure 11, a negative contact print produced from a band 5 positive transparency for April 14, 1973 illustrates the pattern of plowed fields shown as black dots in the central and southern portions

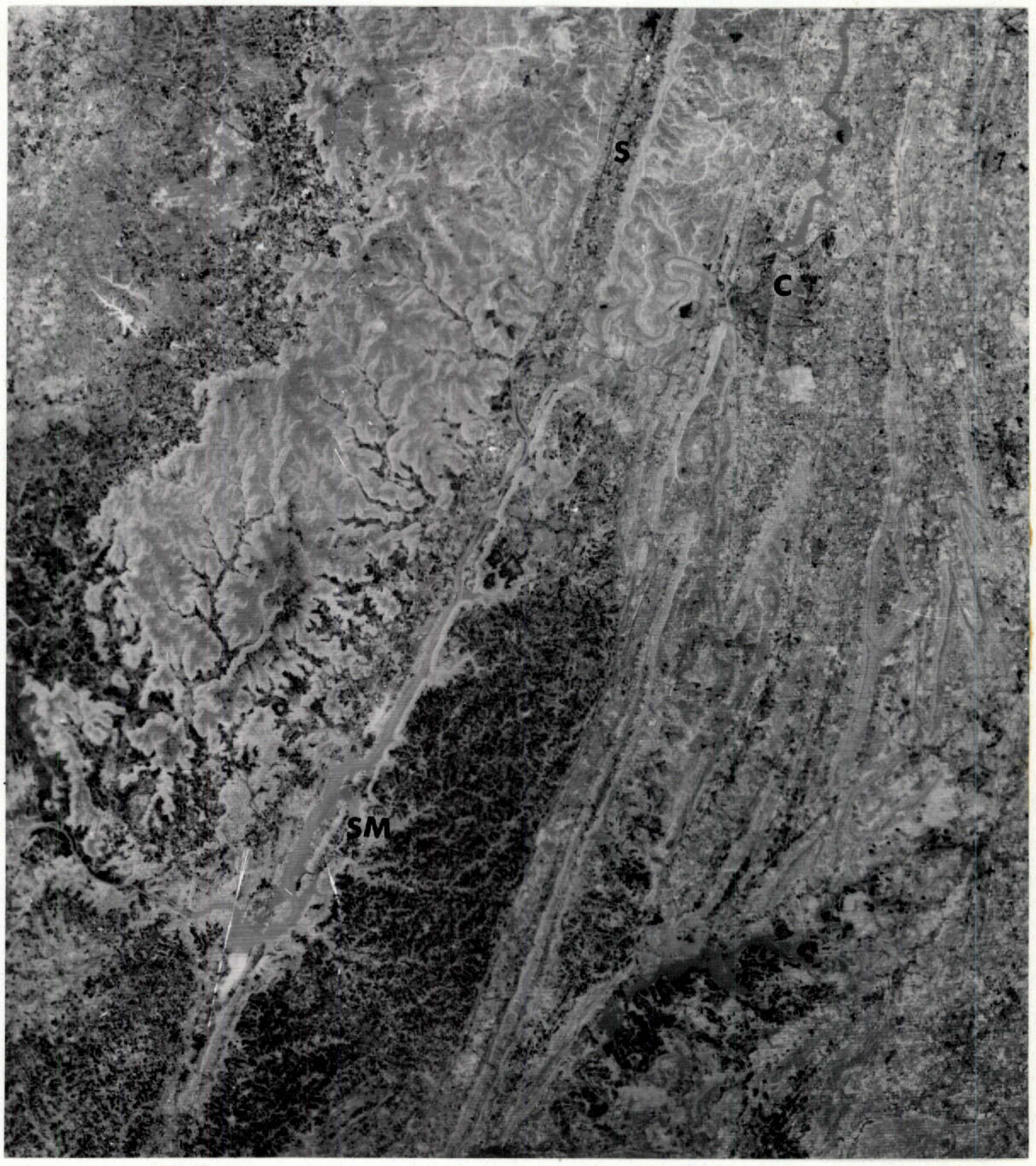

Figure 11. ERTS band 5 negative print showing plowed fields in the Sand Mountain, Alabama area, April 14, 1973

of the image. In general, every dot and line of deepest darkest intensity reflects the existence of a bare soil surface. Most dots and blocks are cleared plowed fields while the dark linear features in the upper center of the photo at C are the roads leading east from Chattanooga.

In the southern portion of the image, Sand Mountain, Alabama (SM) reflects plowing activity to the greatest and most extensive degree. Note the finger-like extensions of agricultural lands reaching into the valley bottoms of the dissected plateau areas west of Sand Mountain. West and northwest of the Cumberland Plateau, the area in light gray tones, we again see the plowed fields of the Highland

Rim and Plateau of the Barrens, landscapes of moderate relief and agriculture. Viewing East and North in the upper center of the image at (S) we can detect minor plowing patterns in Sequatchie Valley. Southeast of this area, the city of Chattanooga, Tennessee (C) is illustrated by dark gray tones and dark lineations of east-west roads on the image. Finally in the southern and eastern portions of the image, significant agricultural areas are evidenced by the concentrated patterns of plowed fields identified in the Gadsden, Alabama - Rome, Georgia area.

In each photomorphic region we can determine a certain and separate degree of tonal unity and distinctiveness.[5] More importantly, a management and landuse distinction exists in each region. On a negative print, light toned forested lands indeed represent a different tonal and landuse quality than do the dark etchings of cleared cultural landscapes. Although forested vs cleared land surfaces are understood in detail here on earth, one requires the region-wide view to analyze such regional variations and to express to the general public the importance of such distinctive regions. In many ways, variations like these in tonal quality, reflect variations in earth resources and thus suggest a different set of values and management principles to be applied to each.[6]

Because man's individual actions in creating landscape change are relatively small on a cell for cell basis, any investigation such as this one requires large area coverage on a periodic basis in order to observe and analyze aggregate changes over an extended period of time. To date, only the ERTS program has readily provided this capability. The continued analysis of data from ERTS-I and, more importantly, from Skylab and ERTS-B would insure a success in the analysis of landscape change from a geographic point of view and would be a contribution in the study of man's role in changing the face of the earth.

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